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FAN VENTILATION OF AIR SPACE ABOVE GRAIN IN FLAT STORAGES

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CONTENTS

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FAN VENTILATION OF AIR SPACE ABOVE GRAIN IN FLAT STORAGES

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SUMMARY

During the summer, temperatures in the overspace (space between the grain surface and the roof) of flat storages are often responsible for drying the surface grain excessively and for shortening the effectiveness of surface protectants. During nights and cool days, moisture from the interior grain may condense on the surface grain and on the underside of the roof--particularly during aeration when air movement is upward through the grain.

Ordinary natural ventilation has not been satisfactory in controlling overspace temperatures and humidities. Studies were conducted during the 1960-61 and 1961-62 storage seasons to determine if fan ventilation provides better control of air conditions in the overspaces of flat grain storages than natural ventilation. Temperatures were recorded in the overspace air, at the grain surface, and at depths of 1/2, 1, 2, and 3 feet into the grain. Airflow rates and fan operating periods were also recorded.

Improved storage conditions resulting from fan ventilation of overspaces include:

1. Savings in the cost of surface protectants.
2. Less moisture (weight) loss from stored grain during the summer months.
3. Improved safety and working conditions for storage workers.
4. Reductions in the costs of preparing storages for general fumigations because of fewer openings to be sealed before and unsealed after fumigating.
5. Minimal moisture condensation on surface grain and on undersides of roofs during nights and cool weather and during periods of aeration when air movement is upward.

BACKGROUND AND PURPOSE OF STUDY

Radiation from the sun in summer causes intense heating of the air in the overspace (air space between the grain surface and roof) of flat grain storages, particularly in the South and Southwest. Formerly, grain was frequently turned (moved from one bin to another) on a regular schedule. Any surface grain heated by radiation was blended with other grain and excessive heating went unnoticed.

With aeration, grain requires little turning and the effect of radiation on the temperature of the grain near the upper surface becomes more apparent. Aerated grain remaining in storage into the summer often has temperatures of 50° to 60° F. The temperature in the overspace may build up to 140° F. or

more when fans are not in use. The surface grain then becomes considerably heated and excessive drying results.

Most aeration systems are designed to move air downward through dry grain. During aeration, heat from the overspace and surface layers of grain is pulled through the grain pile, causing additional drying throughout the grain. The moisture loss from the stored grain may average as much as 2 percent during a storage season, resulting in a monetary loss to the storage firm.

At times, the movement of air upward through warm, wet grain has certain advantages. The grain can be aerated as it is loaded into the storage, and after it has cooled, heat and moisture from later loadings are not pulled through it. However, moisture from the grain may condense on the grain surface and on the underside of the roof. This problem can become serious during nights and cool days.

Most flat storages are equipped with a number of ventilators in the roof and end walls. But ventilators can cause problems in insect control, because the application of most fumigants requires storages that are almost airtight. Air movement through the ventilators can dilute fumigants until they become nonlethal; thus the ventilators must be sealed before each fumigation--a time-consuming procedure. Also, because conventional ventilation may not remove all the fumigant after the ventilators are opened, a hazard is created for workers who must enter the building. Finally, conventional ventilators may fail to prevent loss when volatile surface protectants are used because these protectants rapidly become less effective when they are exposed to high overspace temperatures.

Studies were made to determine if fan ventilation would be more effective than ordinary natural ventilation 1/ in reducing the temperature of the overspace air and the surface grain, in preventing excessive losses in grain moisture and surface protectants, in preventing condensation on roof and grain near the upper surface, and in providing more effective fumigation.

TEST PROCEDURES

Studies were conducted at Mathis and Agua Dulce, Tex. In the first series of tests, conducted during the 1960-61 storage season, a flat storage (fig. 1) with two compartments, each 275 feet long and 80 feet wide, and each equipped with six ridge ventilators, was used to study the effectiveness of fan ventilation of the overspaces. One compartment, used as a check, was not equipped with fans, but relied solely upon its six conventional ridge ventilators. The other compartment was equipped with two 48-inch-diameter fans operated on a 24-hour basis. Each fan was rated to move more than 19,000

1/ Natural ventilation--Ventilation by natural forces available for moving air into, through, and out of buildings, such as (a) wind forces, and (b) differences in temperature between the air inside and outside a building.

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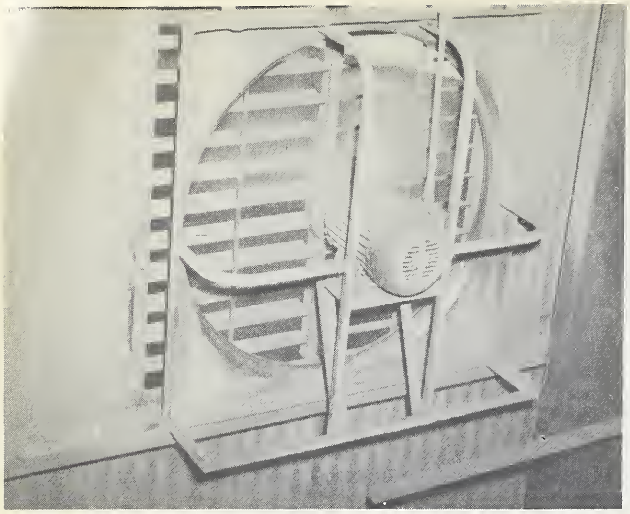
Figure 1.--Flat grain storage used in first series of tests. Compartment at near end was equipped with ventilating fan units; compartment at far end was naturally ventilated with six of the storage's ridge ventilators.

cubic feet of air per minute through the overspace. The two fans were mounted at one end of the compartment. Air pulled into the overspace through a door above the grain at the opposite end of the compartment moved across the surface of the grain before being exhausted through the fans to the outside. During testing, the six ridge ventilators in this compartment were closed.

A recording potentiometer was installed to record temperatures every 2 hours at seven locations in each compartment. Thermocouple junctions for temperature readings were placed as follows: two in the overspace air, one at the grain surface, and one each at depths of 6 inches, 1 foot, 2 feet, and 3 feet into the grain. One junction in the overspace air was placed in a radiation shield to determine if radiation from the roof caused erroneous air temperature readings in the overspace.

In the second test series conducted during the 1961-62 storage season, the same check compartment was used, and two other buildings were added to the studies. Each building was 200 feet long and 80 feet wide, and each was equipped with a fan unit (fig. 2, left) rated to move air at 22,000 c.f.m. through the overspace. Automatic louvers were installed over the fan unit (fig. 2, right) and at the end of the building (fig. 3). The fans moved air through the storage in the same general direction as the prevailing summer winds. Recording thermometers (fig. 4) in each building continuously recorded the overspace air temperature and the grain temperature at the 1-foot depth. Time clocks were used for scheduling the fan operating periods.



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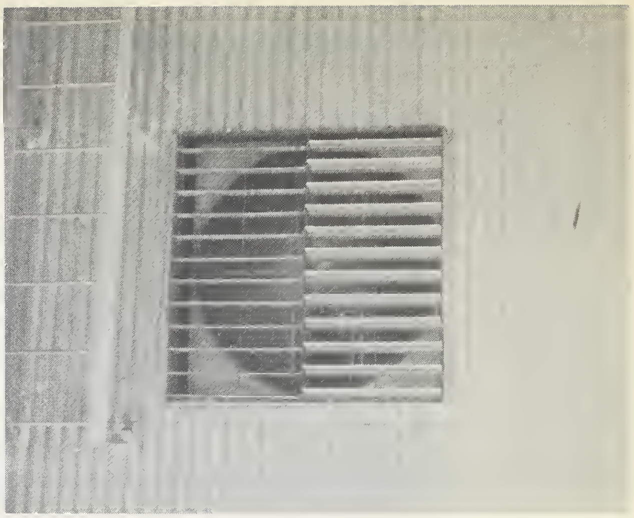

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Figure 2.--Three-horsepower fan (inside storage) added in second test series (left). Automatic louvers were installed outside the storage over the fan (right).

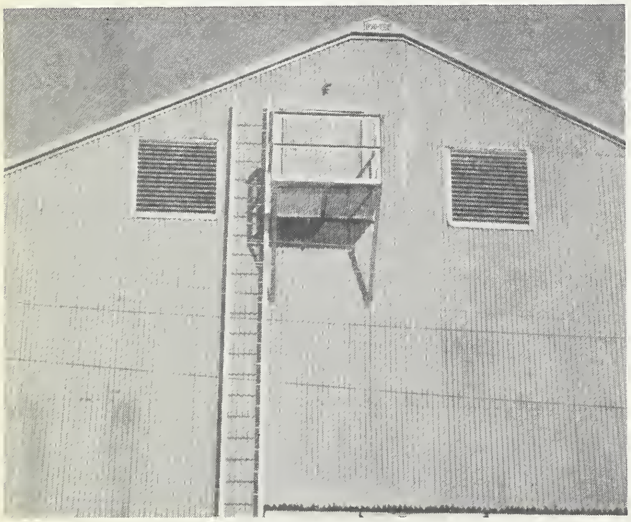

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Figure 3.--Two rainproof automatic louvers installed over air intakes in end of storage opposite fan.

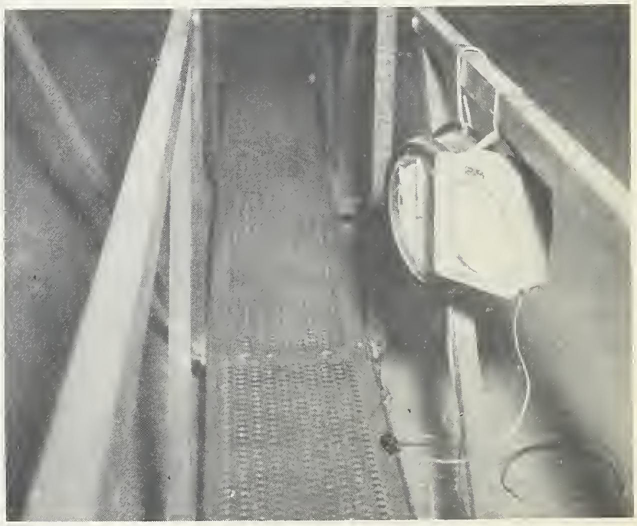

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Figure 4.--Recording thermometers used in tests to record overspace temperature and internal grain temperature.

For one operating schedule the fan was run on a 24-hour basis. For another schedule, the fan was controlled by a time clock that restricted operation to the hottest part of the day only. A third schedule also used a time clock that, in this instance, restricted fan operation to the coolest part of the day only. In each case, the overspace temperatures were compared with those in the check compartment, which was not equipped with fan ventilators.

RESULTS

The daily fluctuation in overspace air temperature was more pronounced with natural ventilation than with fan ventilation. Figure 5 compares hourly overspace air temperatures in a storage using conventional ridge ventilators with those in a storage using fan ventilation. Air temperatures in the overspace were usually about the same in both storages during the night. But during the daylight hours, temperatures rose more rapidly and reached a higher maximum with natural ventilation than with fan ventilation. During April and May the overspace temperature was often 30 or more degrees higher in the storage relying on natural ventilation than in the storage using fan ventilation (fig. 6).

Daily temperatures of the surface grain did not fluctuate as widely as temperatures of the overspace air. However, grain surface temperature rose well above 110° F. during the summer months when natural ventilation was used. Figure 7 compares surface grain temperatures in a storage using conventional ridge ventilators and grain temperatures in a storage using fan ventilation.

In figure 8, temperatures 12, 24, and 36 inches below the grain surface are compared for a storage using natural ventilation and a storage using fan ventilation. Grain temperatures were maintained at a lower level later into the spring with fan ventilation. Temperature data also indicate that overspace temperatures need not be as low as the grain temperature as long as air movement is maintained over the grain surface during daytime hours.

No apparent advantage accrued from operating fans at night, even though overspace air temperatures might be somewhat higher than grain temperatures. Overspace temperatures at night were about the same with continuous fan operation, no operation, or operation restricted to the period between 8 p.m. and 6 a.m. Testing in Texas proved that fans operated only during the hottest part of the day (7 a.m. to 7 p.m.) performed more effectively than fans operated between 8 p.m. and 6 a.m. and compared favorably in effectiveness with fans operated continuously.

ADVANTAGES OF FAN VENTILATION OF OVERSPACES

Fan ventilation of overspaces offers a promising complement to aeration procedures aimed at reducing temperature differences between the grain and the overspace air in flat storages. If the temperature of the overspace air can be held to a reasonable minimum, the grain warms more slowly and temperatures less attractive to insects can be maintained longer during the summer.

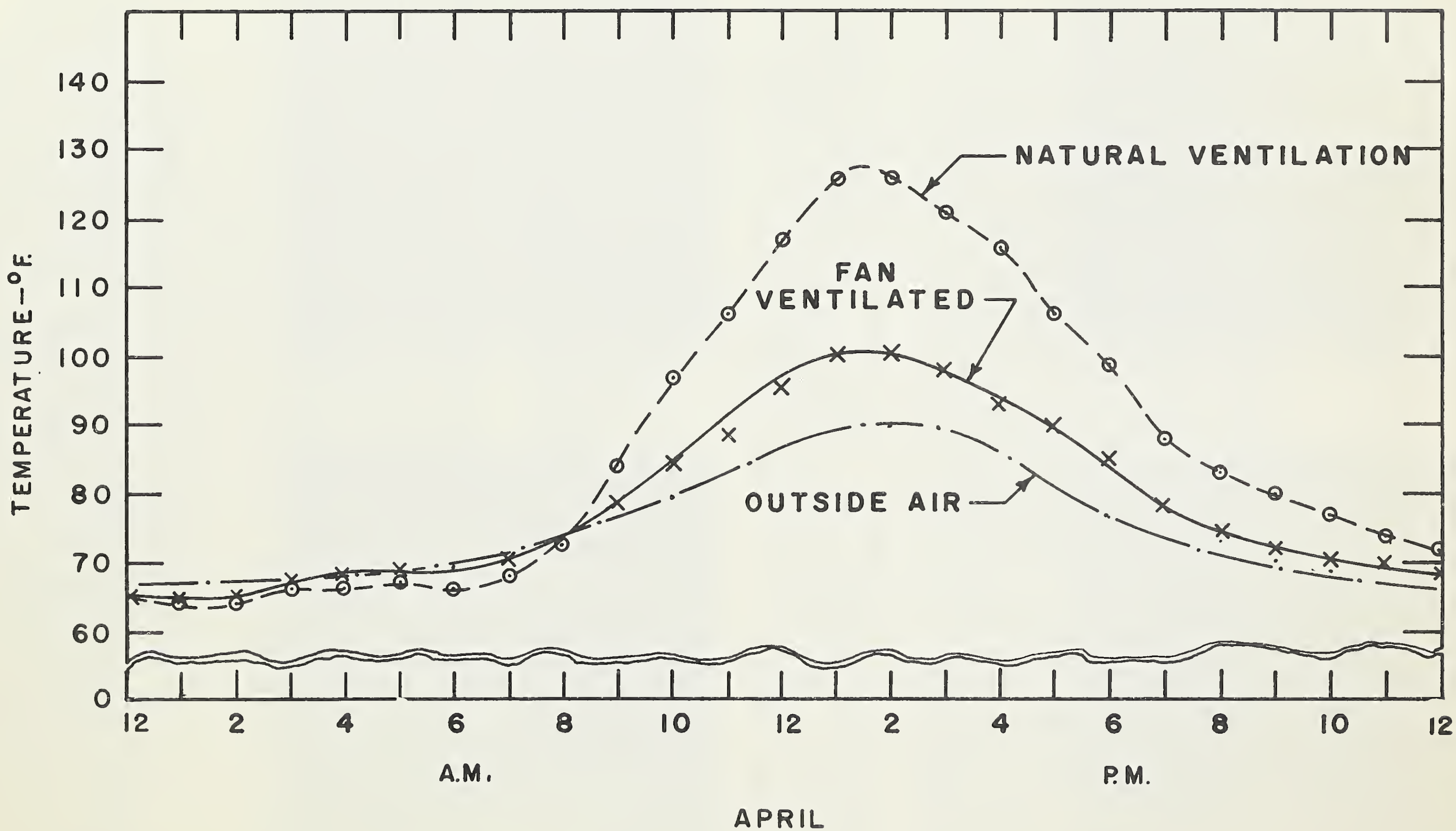

Figure 5.--Averages of hourly fluctuations of overspace air temperatures in storages and of outside air during April 1962.

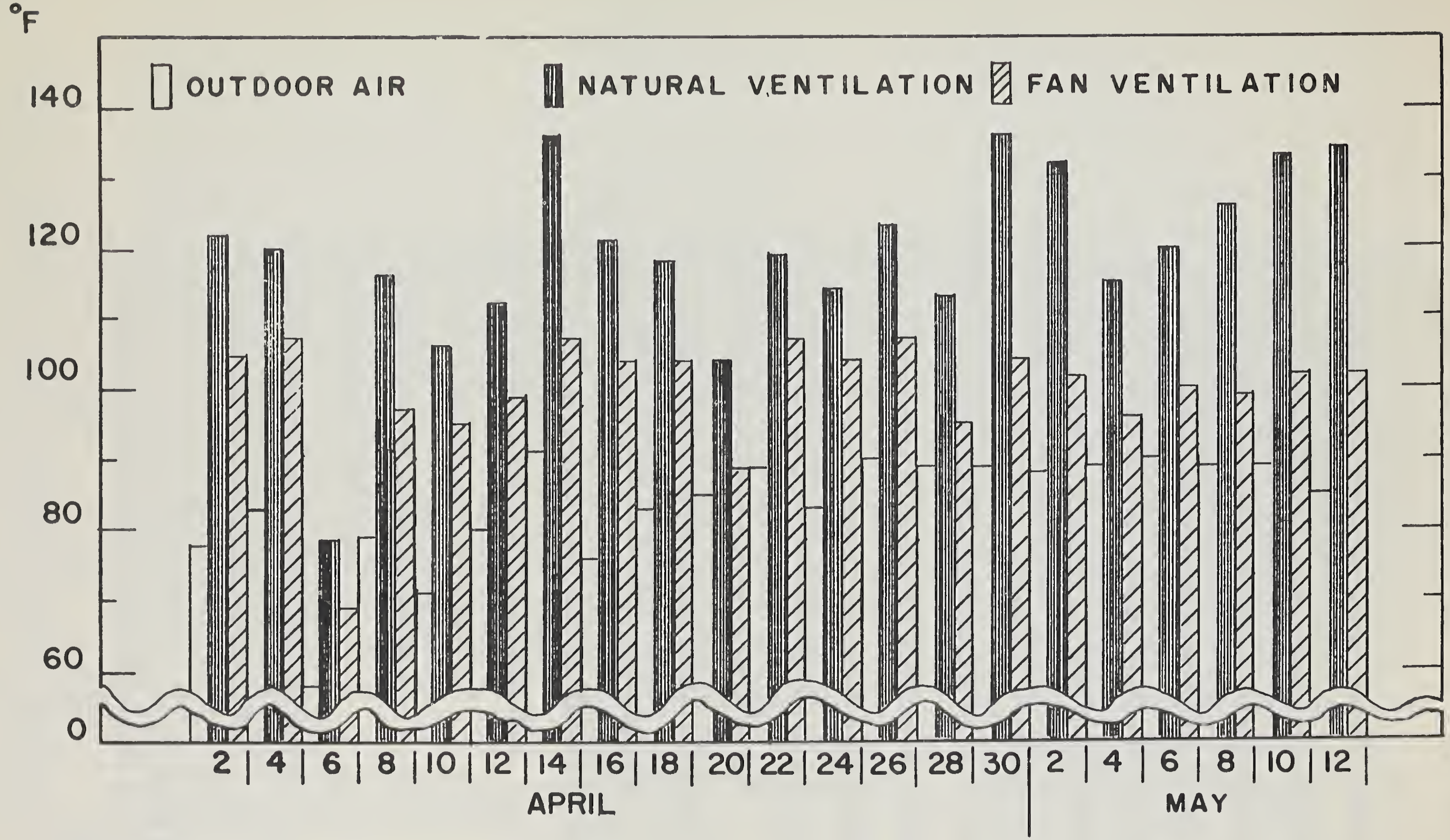

Figure 6.--Two-day averages of highest daily overspace air temperatures in storages and of outside air, from April 1 to May 12, 1961.

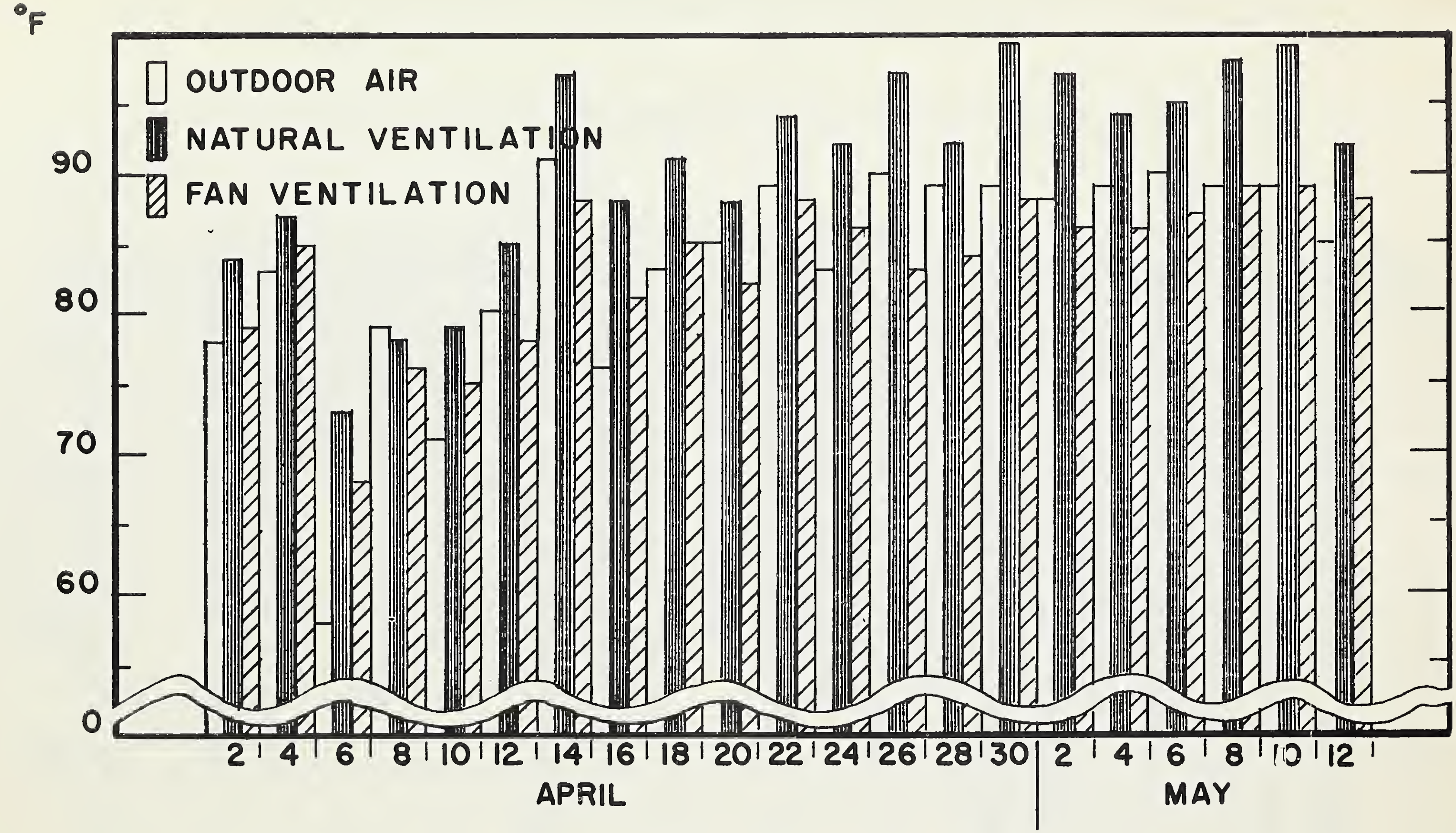

Figure 7.--Two-day averages of highest daily surface grain temperatures in storages and highest outdoor temperatures, from April 1 to May 12, 1961.

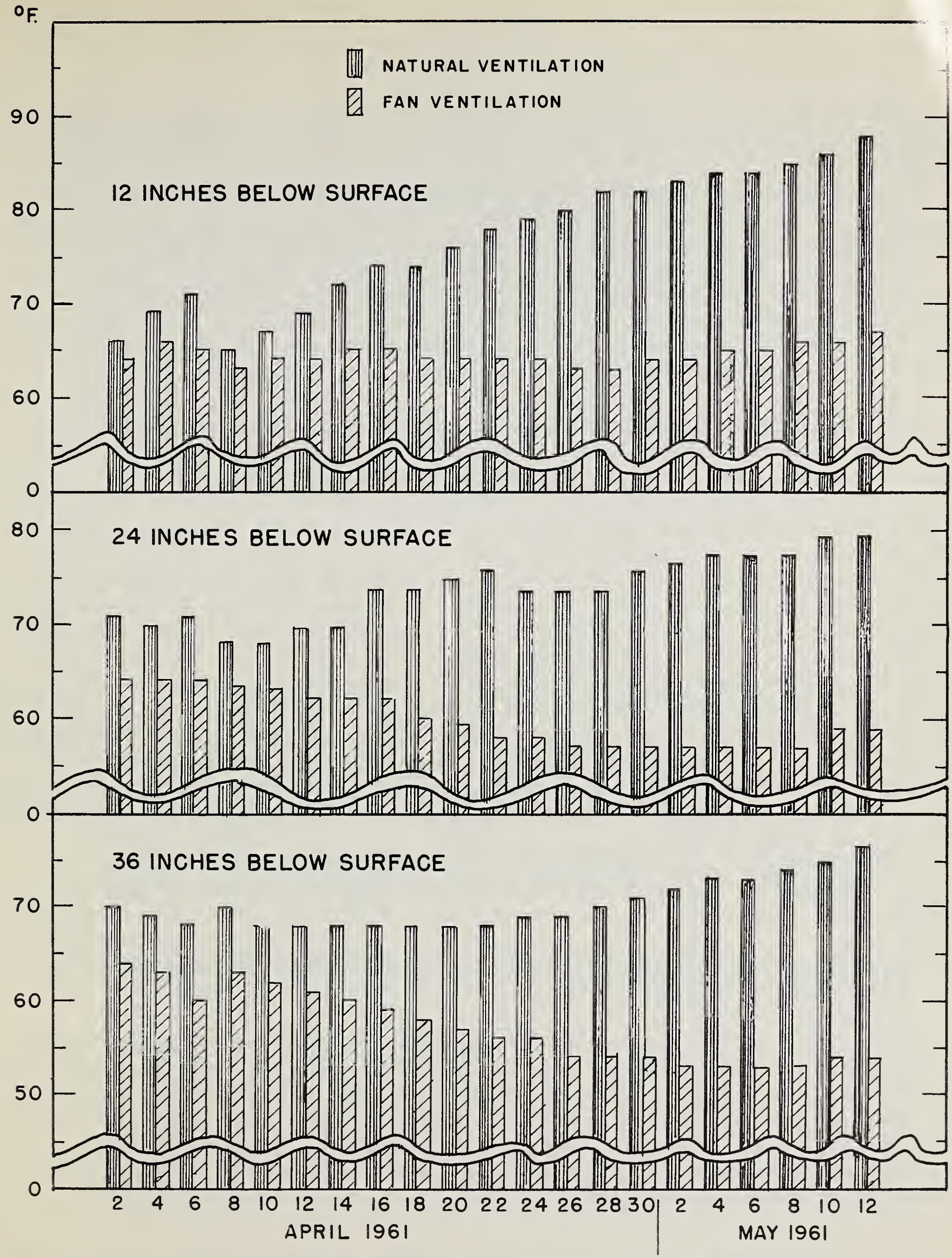

Figure 8.--Two-day averages of daily fluctuations of temperature below surface of grain in storage relying on natural ventilation and storage using fan ventilation, from April 1 to May 12, 1961.

Fans placed properly provide the best method of ventilating the overspace. The air is more uniformly distributed throughout the overspace, and pockets or areas of poor ventilation are eliminated (fig. 9).

Natural ventilation with conventional ventilators does not bring about rapid changes of air in the overspace. Often the only air movement through the ventilators results from a pressure difference between the overspace air and the air outside the building. The air in the overspace expands as it heats, increasing the pressure in the overspace. The lighter, warmer air rises and is replaced by heavier, cooler outside air. Heated air is expelled through the ventilators until the pressures of the overspace air and outside air are again equal. To increase the rate of air change with conventional roof ventilators, cooler outside air must be allowed to enter near the grain surface. Such air inlets are not usually provided in flat storages since they present a problem when the building is sealed for fumigation.

The usual methods of locating the ventilators on the ridge of the roof or scattering them over the roof area, as shown in figure 1, do not eliminate areas or pockets with little or no ventilation (fig. 10).

Surface grain in storages with no fan ventilation of the overspace usually loses as much as 3 or 4 percent moisture during the storage season. The temperature and relative humidity of air in contact with the surface grain are constantly changing. At night the air is cooler and its relative humidity is comparatively high. During daylight hours radiation from the sun may raise the temperature of the overspace air high above 100° F. and may cause its relative humidity to fall to a low level. The grain, being hygroscopic, tends to remain in equilibrium with the air around it by gaining or losing moisture. When the temperature of the overspace air is high, surface grain temperatures increase with a corresponding increase in the vapor pressure of the grain. Then the grain can give off moisture to the air. Fan ventilation provides more uniform temperatures than natural ventilation to minimize the loss of moisture from surface layers.

Results of aeration research in the Southwest showed that the higher the initial grain temperatures, the greater the evaporation rate from grain during aeration. 2/ Thus, if a large amount of heat accumulates in the surface grain and this heat moves through the grain during aeration, excessive moisture will be lost throughout the grain pile.

In the past few years, workers have been poisoned by entering grain storage buildings before the fumigants were entirely removed. In some instances, the overspace was ventilated with conventional methods, but pockets or areas of high fumigant concentrations remained. Fan ventilation has been effective in removing pockets of fumigants, and no poisonings have been reported in buildings where such ventilation has been used, either after fumigating or while laborers are inside the building.

2/ Hutchison, R. S., and Williams, E. F. Operating grain aeration systems in the Southwest. U.S. Dept. Agr. Mktg. Res. Rpt. 512, 20 pp., illus. 1962.

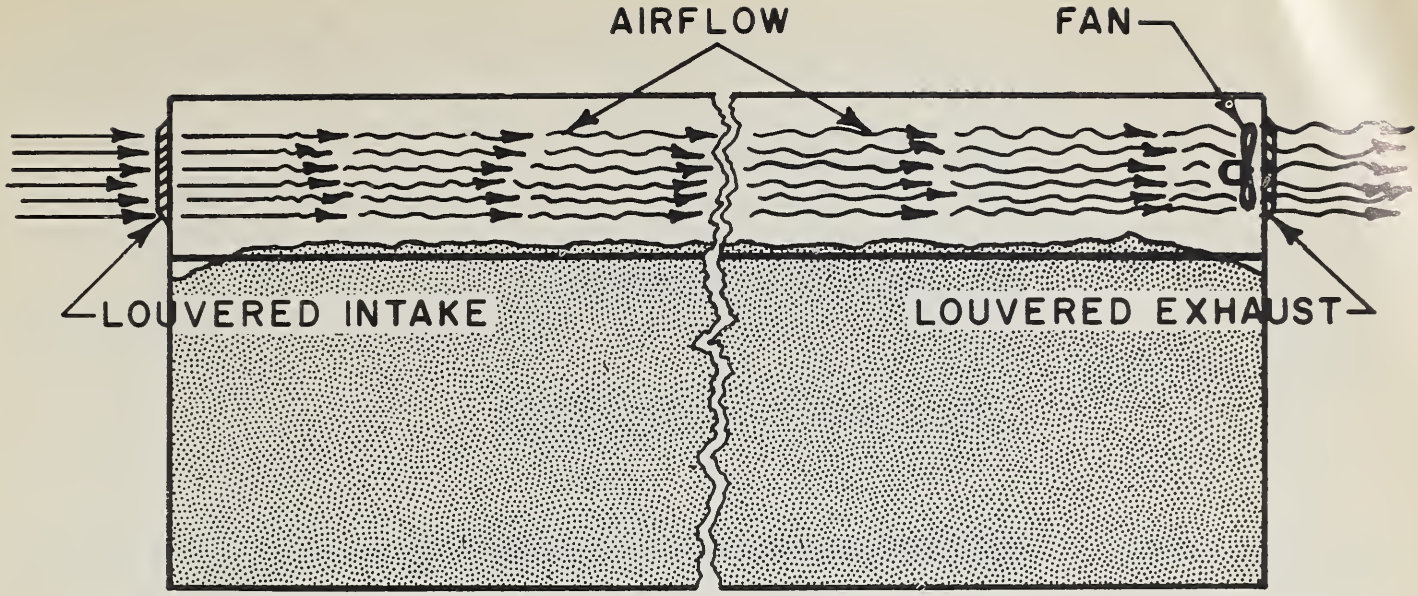

Figure 9.--Ventilation from properly positioned fans provides a positive, well-distributed, uniform flow of air through overspaces in flat grain storages.

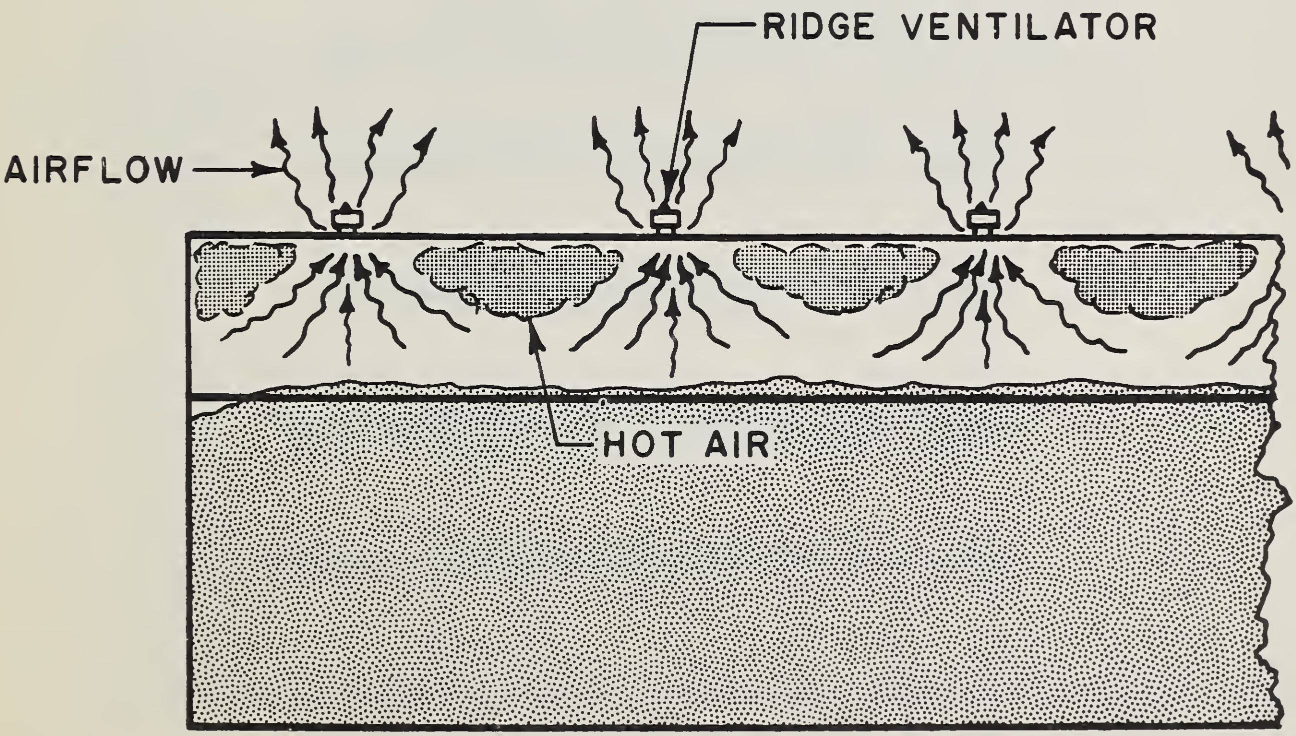

Figure 10.--Conventional ridge ventilators leave pockets with little or no ventilation in the overspaces of flat grain storages.

When a grain storage with natural overspace ventilation is to be fumigated, each ventilator must be tightly sealed. However, sealing ventilators requires an investment in time and materials. The type of ventilators generally used do not close tightly enough to prevent the fumigant from escaping. The most common method of sealing them adequately is to cover them with an airtight cover that is usually fastened with masking type. In an average-sized flat storage, this usually requires two laborers to work from 1/2 to 1 day. Buildings with fans, on the other hand, have only a few openings, which can be easily sealed--the air inlets in one end and the air outlets in the other end of the storage. Also, much less time is required to remove the sealing material when the fan ventilation system is used.

OPERATING SCHEDULES

Fan ventilation is more beneficial during the summer than during other seasons. However, operating the fans on warm, sunny days in the spring, fall, and winter can be helpful in maintaining lower overspace and surface grain temperatures.

Overspace fans can be used to advantage when aeration systems move air upward through warm, moist grain. Fans should be operated continuously during aeration periods to remove warm, moist air from the overspace and thus minimize condensation on surface grain and on the underside of the roof.

Overspace fans can be operated during rainy periods if rain is not pulled into the storage through louvers, cracks, or other openings.

Time clocks should be used to control fan operation and should be checked regularly to assure proper setting. Thermostats are not very satisfactory for controlling fan operation. They require much more attention than time clocks since they have to be reset for variations in air temperatures during the different seasons.

LOCATIONS OF FAN

The prevailing wind direction during operation of the ventilating fan has a decided effect on the efficiency with which it functions. If the fan discharges into the wind rather than downwind, the amount of warm air removed from the overspace may be reduced by 50 percent or more. If the fan discharges downwind, the wind aids the fan and much more air is moved through the overspace. Figure 11 compares the effectiveness of a fan discharging against the wind with that of a fan discharging with the wind. If louvers are used, they may be closed by wind blowing against them and the amount of warm air discharged from the storage will be reduced. The placement of the storage on the site with respect to the wind direction may have an effect on air movement through the overspace. Figure 12 shows the effect of storage orientation on the temperature in the overspace.

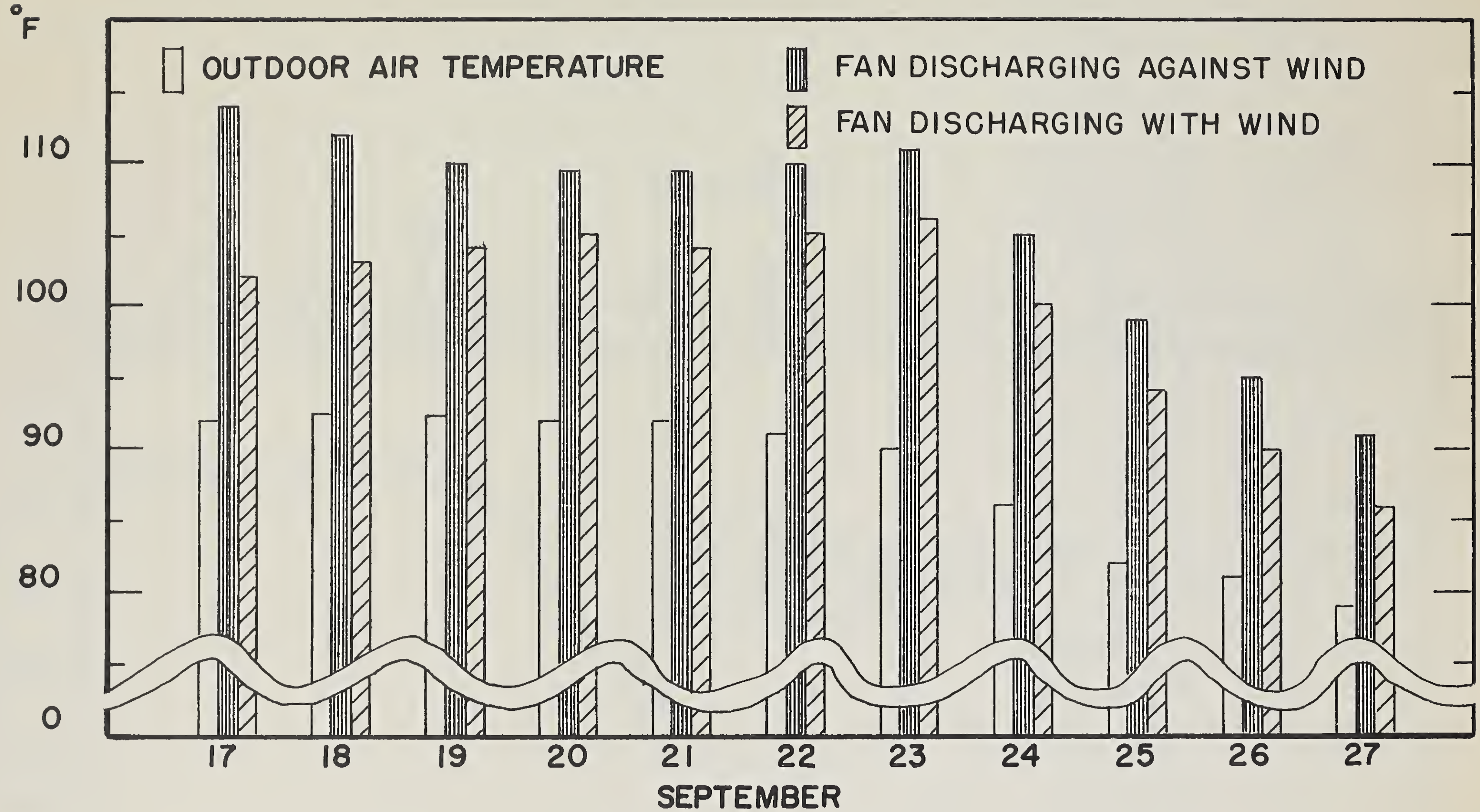

Figure 11.--Daily fluctuations in overspace air temperatures in storages according to location of fans and wind direction, from September 17 to 27, 1960.

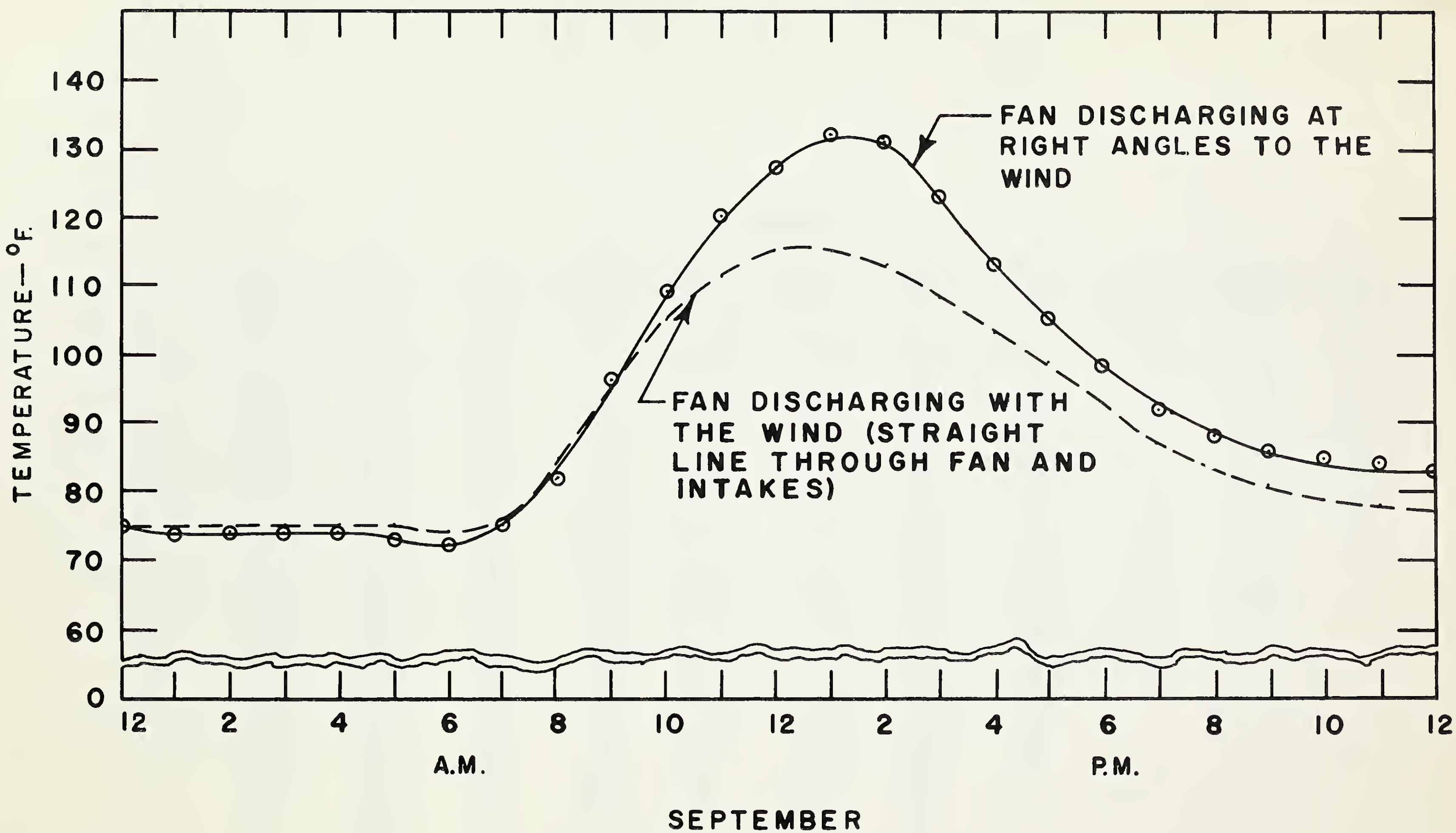

Figure 12.--Averages of hourly fluctuations of overspace air temperatures in storages according to building orientation and wind direction on September 26, 1961.

COST OF FAN VENTILATION

The installed cost of fan ventilation systems for overspaces is low. Low-cost fan units capable of providing an air change every 3 minutes in the overspace are suitable for aeration purposes. Although the size and shape of the overspace above the grain in a storage has a decided effect on the cost of fans needed to ventilate the overspace, the installed cost should range between $200 and $500 per storage (1967). The amount of additional electric wiring needed can affect the cost measurably.

The electricity required for operating overspace fans is not a major cost item in the management of a grain storage. Some operators have found that it adds nothing to an electric power bill that is paid on a minimum monthly basis. In any case, the cost is seldom more than two-tenths of a cent per bushel per calendar year of operation. This cost should be more than offset by the improved storage conditions resulting from fan ventilation.

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